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OFF-SHORING, SPECIALIZATION AND R&D

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This paper investigates whether off-shoring promotes technological specialization by reallocating resources towards high-tech industries and/or stimulating within industry R&D. Using data for the USA, Japan and Europe, our results show that material off-shoring promotes high-tech specialization through input reallocation between sectors, while service off-shoring favors technologically advanced production by increasing within-industry productivity, mainly via its positive impact on R&D. Conversely, we find that the increasing fragmentation of core production tasks, captured by narrow off-shoring, has adverse effects on technological specialisation, which suggests that this type of off-shoring is mainly pursued for cost-reduction motives.

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1. INTRODUCTION

The phenomenon of off-shoring, the foreign outsourcing of intermediate inputs,[1] has often been associated with negative labor market outcomes, such as lower wages and higher unemployment rates for unskilled workers in the off-shoring countries (Wood 1995, Jones and Marjit 2001, Hijzen *et al*. 2005, Bloom *et al*. 2016). The more recent phenomenon of service off-shoring has also generated concerns over possible negative consequences on high and intermediate

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[1]For an early contribution on foreign outsourcing see Katz and Murphy (1992) and Feenstra and Hanson (1996).

skilled workers, who represent a large share of employment in the service sector (Freund and Weinhold 2002).

This paper looks at off-shoring from a different perspective which has been less investigated in the empirical literature but can have an effect on countries' long-term performance: the impact of off-shoring on the pattern of specialization. The sources of specialization are crucial drivers of a country's international competitiveness and growth performance and they have frequently been the target of major industrial policies, aimed at developing strategic sectors.[2] Understanding how new developments in trade are changing specialization is therefore of primary interest to economists and policy makers.

Early assessments of the relationship between off-shoring and specialization are provided by Jones and Kierzkowski (1990) and Jones and Marjit (2001). These contributions suggest that the breaking up of production into different components opens new possibilities for exploiting 'gains from specialization,' particularly when technological advances strengthen these trends by reducing costs (for example in telecom services) and weakening the importance of geographical distance.[3] If unskilled labor-intensive activities are transferred to a foreign country, the average skill intensity of the remaining home activities will rise (Barba Navaretti and Falzoni 2004). This would bring particularly high gains for the home country if off-shoring induced a transfer of national resources towards more high-tech and knowledge intensive production. On theoretical grounds, this consideration is compatible with the Heckscher-Ohlin (HO) model: by accessing cheaper inputs from abroad, companies in skill intensive countries will restructure production towards more skill intensive tasks (Glass and Saggi 2011). Some evidence in this respect is provided by Bloom *et al*. (2016) with reference to the increasing exposure of the US to Chinese imports of both final and intermediate goods.[4] This study shows that the intensification of the USA-China trade relationship is positively related to productivity and patenting activities. In a similar line of argument, Görg and Hanley (2011) find a positive relationship between service outsourcing and innovation in Irish companies. However, a detailed analysis of the mechanisms that govern the relationship between off-shoring, specialization and R&D is still missing from the literature.

This paper investigates these mechanisms using a panel of seventeen industries for eight OECD countries (Denmark, Finland, Germany, Italy, Japan, Netherlands, UK and USA), observed over the 1990–2005 period. Our data set includes both manufacturing and service industries, providing a comprehensive

[2]For example, the Japanese specialization in high-tech industries was favored by a mix of R&D subsidies, preferential access to credit and protectionist measures (Noland 1993). Studies that recognise the importance of specialization for growth include Grossman and Helpman (1991) and Barro and Sala-i-Martin (2003), among others.

[3]Jones and Marjit (2001) discuss in detail the consequences of the fragmentation of production on prices and income distribution, as well as emphasising the role played by the internationalisation of services.

[4]The main message derived from this study is that increasing import competition from China in final goods induces technological change and reallocation of employment towards more productive tasks. The same effect is also taking place when there is intensive off-shoring to China, which releases resources towards patenting activity and thus spurs productivity of US firms.

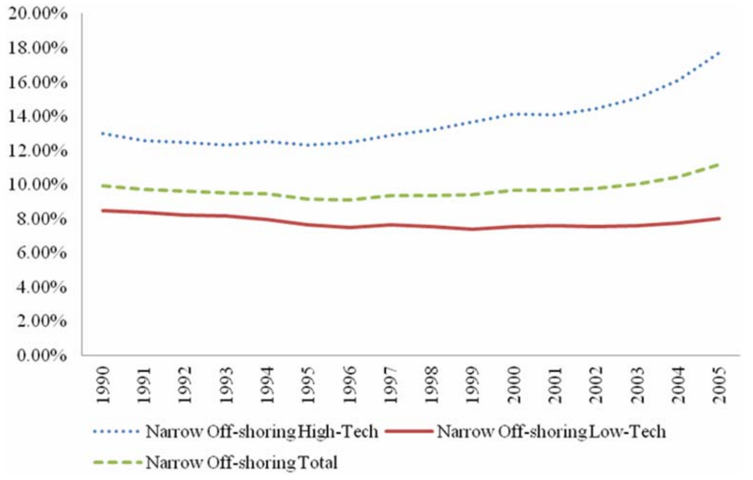

Figure 1. International fragmentation of production, 1990–2005, percentage of industry value added (cross-country average) [Colour figure can be viewed at wileyonlinelibrary.com]

Note: The graph is drawn from the sample of eight countries used in the present study. See Section 3 for full data description.

analysis of the changes in countries' industry structure. Our analysis uses three measures of off-shoring: within-industry off-shoring, material and service off-shoring (Feenstra and Hanson 1999). The measure of within-industry off-shoring is a narrow indicator that refers to imports of intermediates from foreign firms operating in the same sector. As such, this definition of off-shoring is particularly suitable to capture the effect of industry fragmentation on specialization, a phenomenon that has sizeably increased over the last few decades (Feenstra and Hanson 1996). The measures of material and service off-shoring are considered as broad indicators, i.e. they trace imports of intermediate materials and services from any foreign industry. Using these three indicators allows us to explore the effects of all possible off-shoring strategies on specialization.

Figure 1 shows average trends in within-industry off-shoring in our data set. Industries are divided into high-tech and low-tech, following the OECD/Eurostat definition. The figure clearly shows that, from the mid-1990s, off-shoring has been an increasingly popular practice within the group of high-tech sectors. Therefore, the key question is whether international outsourcing has driven changes in specialization, and in particular through which channel this impact operates, i.e. whether by favoring resources reallocation towards high-tech industries or by delivering productivity gains, for instance through greater efforts in R&D activities.

To analyze the impact of off-shoring on specialization we develop an analytical framework which accounts for off-shoring and the traditional drivers of specialization, i.e. productivity advantage (Ricardo) and factor endowments (Heckscher-Ohlin). The main assumption is that off-shoring affects specialization via two channels: an *endowment* and a *productivity channel*. The *endowment channel* follows from a recent contribution by Baldwin and Robert-Nicoud (2014), which integrates off-shoring within the Heckscher-Ohlin theory.[5] In this setting, the productive services of foreign factors are allowed to migrate to the home nation while being paid foreign wages, implying that off-shoring can be regarded as "shadow migration." Under this perspective, one can consider off-shoring as an additional endowment next to the standard set of nation-wide factor supplies. The *productivity channel* investigates whether there is a positive relationship between off-shoring and productivity performance, as discussed in Feenstra and Hanson (1996, 1997), Daveri and Jona-Lasinio (2008) and Grossman and Rossi-Hansberg (2008), among others.[6] This positive relationship is a consequence of cost-saving strategies, pursued via off-shoring (Deardorff and Staiger 1988, Markusen and Venables 1999), and the reallocation of resources to more productive tasks in the home country (Farrell and Agrawal 2003, Bloom *et al*. 2016).

The modelling framework outlined above examines whether off-shoring leads to a re-distribution of resources across industries. However, off-shoring is also likely to lead to a re-distribution of resources within industries, by promoting investments in high value added activities. Recent evidence at the firm level shows that companies who off-shore parts of their production are more innovative and profitable (Görg and Hanley 2011). Here we examine this relation in a multi-country setting using a model which expresses R&D expenditure as a function of our off-shoring measures, next to other standard covariates.

To summarize, our analysis tests the following main hypotheses:

H1: *Off-shoring directly drives specialization across sectors by re-allocating resources away from low-tech towards high-tech industries.*

This hypothesis is investigated using the endowment channel. Our expectations are of a positive and significant effect of the *off-shoring endowments* in high-tech industries.

H2: *Off-shoring drives specialisation by improving within-industry productivity.*

This hypothesis is tested using the productivity channel, and aims to understand whether greater productivity gains induced by off-shoring feedback into specialisation patterns. A corollary of *Hypothesis 2* forms *Hypothesis 3*, which directly relates off-shoring to investments in R&D:

H3*: Off-shoring promotes investment in R&D.*

We test H3 by estimating industry-level equations for R&D intensity.

Our results for the endowment channel show that material off-shoring is beneficial for the expansion of several high-tech industries, providing support to *Hypothesis 1*. The size of the effect is not trivial. For example, in the transport equipment industry a 1 standard deviation increase in material off-shoring leads

[5]Following Feenstra and Hansen (1996) we use a definition of off-shoring which includes the import of intermediate inputs by domestic firms as well as the fragmentation of production into discrete activities which are then allocated across countries. The latter is the definition that Baldwin and Robert-Nicoud (2014) refer to.

[6]In assessing the potential implications of trade in high-tech services in the USA, Jensen (2008) claims that the service sector is moving towards skill and technology intensive activities, with significant advantages in terms of productivity and employment growth.

to 0.5 standard deviation increase in value added shares. The role of service off-shoring in the endowment channel is less relevant. However, the productivity channel reveals that service off-shoring plays a relatively more important role in increasing within-industry productivity, partly via its positive impact on R&D intensity. Narrow off-shoring has a limited effect on productivity and a predominantly negative impact on R&D intensity. This supports the notion that narrow off-shoring is primarily pursued for cost-reduction motives and explains why firms have in-shored significant portions of their core activities in the years following the financial crisis, when uncertainty and costs associated with international fragmentation of production increased significantly (Ancarani *et al.* 2015).

The paper is structured as follows: Section 2 illustrates the key features of the analytical framework used to identify the endowment and productivity channels and the relation between off-shoring and R&D intensity. Section 3 describes the data and presents the main trends in specialization, off-shoring and R&D intensity. Section 4 discusses the econometric strategy, describing the identification issues in our three models and the instrumental variable strategy we pursue. Section 5 presents our results and Section 6 concludes the paper.

2. Theoretical Framework

2.1. *Endowment and Productivity Channels*

The empirical identification of the endowment and productivity channels starts with a neoclassical set-up (Dixit and Norman 1980, and Kohli 1991) that identifies a country's GDP as a function of final goods prices and factor endowments. The modification of the national revenue function results in a reduced-form model, identical to the Rybczynski equation that describes each industry's output share to GDP as a function of industry-specific productivity and national factors endowments (Harrigan 1997).

More specifically, we consider a small open economy that produces I final goods, indexed by i, using a set of factor endowments J index by j. The production technology is subject to constant returns to scale and both product and factor markets operate under perfect competition. In equilibrium, the economy maximizes national output. Assuming a translog national revenue function, we can derive a relationship that describes industry i's output share to GDP as a function of nation-wide factor endowments, productivity parameters and final good prices (Dixit and Norman 1980, Woodland 1982, Kohli 1991, and Harrigan 1997):

$$(1) \qquad s_{i,c,t}=\alpha_{0i}+\sum_{m=2}^{I}\alpha_{m.i}\ln\left(\frac{P_{i,c,t}}{P_{1,c,t}}\right)+\sum_{m=2}^{I}\alpha_{m,i}\ln\left(\frac{\theta_{i,c,t}}{\theta_{1,c,t}}\right)+\sum_{j=1}^{J}\beta_i^j\ln\left(\frac{V_{c,t}^j}{V_{c,t}^1}\right)$$

where s denotes industry i's share in country c's GDP in year t, P is industry i 's output price, θ is industry i's productivity and V stands for the measure of endowment j. Symmetry of cross-effects requires that all $\alpha_{m.i}=\alpha_{i,m}$, where $i,m\in\{1,\ldots,n\}$ index industries. Linear homogeneity in the revenue function implies that $\sum\alpha_{m,i}=\sum\beta_i^j=0$ and all right-hand side terms in equation (1) are normalized relative to a reference point. Equation (1) assumes that productivity θ is Hicks-neutral, which implies that technical change is not biased towards specific factors thus it can enter symmetrically the prices vector of the aggregate revenue function. Admittedly, this is a restrictive assumption for the evolution of technical change, especially within a framework that seeks to understand the off-shoring effects of specialization. To consider input-biased technical change is beyond the scope of the present analysis but the investigation of Hypothesis 2 allows the productivity effect of off-shoring to vary with the type of off-shoring (i.e. material and service).

Equation (1) identifies general equilibrium effects of productivity performance of industry m on industry i's output. To avoid over-parameterization we condense the cross-industry productivity effects with term $\bar{\theta}_{m,c,t}$, which represents the average national productivity across industries (i.e. for $m \neq i$) in year t. Finally, we follow Harrigan and Zakrajšek (2000) in assuming that the impact of output prices P is captured by a set of country and time fixed effects, $\sum_{m=2}^{I} \alpha_{m.i} \ln \left(\frac{P_{i,c,t}}{P_{1,c,t}}\right) = d_c + d_t + \varepsilon_{i,c,t}$. Hence, we arrive at the following error-component specification for output shares:

$$s_{i,c,t} = \alpha_{0i} + \alpha_{1i} \ln \theta_{i,c,t} + \alpha_{2i} \ln \bar{\theta}_{m,c,t} + \sum_{j=1}^{J} \beta_i^j \ln \left(\frac{V_{c,t}^j}{V_{c,t}^1} \right) + d_c + d_t + \varepsilon_{i,c,t} \tag{2}$$

In the empirical implementation of the above model, the productivity parameter θ is approximated by a Relative Total Factor Productivity (RTFP) index, while the within-country cross-industry productivity effects are captured by the cross-industry average RTFP.[7]

The first channel for identifying off-shoring effects on specialization is to include off-shoring in the pool of national endowments that each industry has access to. This is defined as the *endowment channel* and builds upon Baldwin and Robert-Nicoud (2014) proposition that off-shoring can be viewed as shadow migration and thus it can be included within the vector of national endowments V. Our model distinguishes between material and services off-shoring. Therefore, the empirical counterpart of equation (2) is written as (common time dummies are omitted for sake of simplicity):

$$\begin{aligned} s_{i,c,t} = {} & \alpha_{0i} + \alpha_{1i} \ln RTFP_{i,c,t} + \alpha_{2i} \frac{1}{n-1} \sum_{m \neq i}^{n-1} \ln RTFP_{m,c,t} + \\ & \beta_{1i} MOS_{c,t} + \beta_{2i} SOS_{c,t} + \beta_{3i} \ln K_{c,t} + \beta_{4i} \ln SK_{c,t} + \beta_{5i} UNSK_{c,t} + \varepsilon_{i,c,t} \end{aligned} \tag{3}$$

In equation (3) MOS and SOS are respectively the economy-wide intensity of material and service off-shoring, K denotes national endowment of fixed capital

[7]In related works, such as Harrigan (1997), cross industry productivity effects are captured by individual industries' relative TFP. We adopt a more parsimonious modelling, which is justified on the econometric ground, due to the larger number of industries included in the analysis. See also Cadot and Shakurova (2010) for a similar adjustment.

stock, SK and $UNSK$ are working age population with high, and low-levels of education, respectively. $RTFP_{i,c,t}$ is the relative level of productivity in industry i and $RTFP_m$ is the cross-industry average in the country excluding industry i. A positive and significant estimate for $\hat{\beta}_1$ and $\hat{\beta}_2$ for high-tech industries, and a negative value for the low-tech ones, would provide support for the hypothesis H1 that off-shoring contributes to reallocation of resources towards more innovative industries.

The second approach, the *productivity channel*, uses Grossman and Rossi-Hansberg's (2008) conceptualization that off-shoring is identical to technical change directed towards industries that make extensive use of international outsourcing. To capture this notion we assume that productivity evolves as a result of industries' off-shoring activities.[8] Therefore, we model RTFP, the empirical counterpart of productivity parameter θ as a function of off-shoring:

$$\theta_{i,c,t} \equiv RTFP_{i,c,t} = \gamma_{0i} + \sum_{z=1}^{3} \phi_i^z G_{i,c,t}^z + \rho_i \mathrm{x}_{i,c,t} + \omega_{i,c,t} \tag{4}$$

where z stands for three different types of off-shoring G, namely material, service and narrow off-shoring, x is a vector of other productivity control variables and ϕ, ρ are parameters to be estimated. Finally, we augment the productivity equation with an I.I.D error term $\omega_{i,c,t}$.

Combining equations (4) and (2) we estimate the effects of off-shoring on specialization via the productivity channel, on the basis of the two following equations:

$$\begin{aligned} s_{i,c,t} = \alpha_{0i} + \alpha_{1i} \ln RTFP_{i,c,t} + \alpha_{2i} \frac{1}{n-1} \sum_{m \neq i}^{n-1} \ln RTFP_{m,c,t} \\ + \beta_{3i} \ln K_{c,t} + \beta_{4i} \ln SK_{c,t} + \beta_{5i} UNSK_{c,t} + \varepsilon_{i,c,t} \end{aligned} \tag{5.1}$$

$$\ln RTFP_{i,c,t} = \gamma_{0i} + \sum_{z=1}^{3} \phi_i^z G_{i,c,t}^z + \rho_i \mathrm{x}_{i,c,t} + \omega_{i,c,t} \tag{5.2}$$

Equations (5.1)–(5.2) identify productivity shifts over time as a function of off-shoring. We assume that off-shoring activities contribute to a more efficient reallocation of resources, which is expected to impact positively on industry's productivity, thus increasing output shares to GDP (Hypothesis H2).

2.2. *Off-shoring and R&D Intensity*

To explore further the off-shoring effects on productivity, we consider whether off-shoring contributes directly to a reallocation of resources towards standard drivers of productivity such as R&D (Griliches 1992). Theoretical

[8]Feenstra and Hanson (1997) model TFP as a function of foreign outsourcing. For some empirical evidence about the contributions of off-shoring to productivity improvements see Girma and Görg (2004), Amiti and Wei (2009), Hijzen *et al.* (2010).

models of this relationship predict mixed results (Naghavi and Ottaviano 2009, Glass and Saggi 2001), which mainly indicate that R&D gains derived from off-shoring depend on the type of activities off-shored, as well as on the type of off-shoring destinations. In the present context, we seek to identify whether off-shoring economizes resources that can be alternatively used to intensify R&D activity in the home country. To this end, we estimate a specification where R&D intensity at the industry level (*RDI*) is regressed on off-shoring measures, together with a set of country and time dummies:

$$RDI_{i,c,t}=\lambda_{0,i}+\sum_{z=1}^{3}\varphi_i^z G_{i,c,t}^z+d_c+d_t+u_{i,c,t} \tag{6}$$

where d_c and d_t are a set of country and time dummies respectively, and G is off-shoring. The notation is the same as in equations (4) and (5) where z denotes the type of off-shoring and φ_i^z is the coefficient of interest.[9] If off-shoring promotes investments in R&D, as assumed in our third hypothesis (H3), we expect this coefficient to be positive and statistically significant. To maintain consistency with our benchmark theoretical specifications (1) and (2), we estimate equation (6) for each industry separately after pooling observations across countries and years.

3. Measurement and Data Issues

Our empirical analysis is based on a sample of 17 industries (12 manufacturing industries and five service industries) for the USA, Japan and six EU countries (Denmark, Finland, Germany, Italy, Netherlands and UK). The estimation of equations (3), (5.1), (5.2) and (6) requires substantial prior work to construct industry specific and country specific variables. This section provides definitions of variables and illustrates the main trends in off-shoring, specialization and R&D.

3.1. *Off-shoring Measures*

The construction of the off-shoring indicators follows the methodology described in Feenstra and Hanson (1999, 2003). We start by defining the following measure of total off-shoring (TOS):

$$TOS_{i,c,t}=\frac{\sum_{f=1}^{F} III_{i,c,t}^{f}}{NE_{i,c,t}} \tag{7}$$

where $III_{i,c,t}$ are imported intermediate inputs from all foreign industries f, $NE_{i,c,t}$ are total purchases of non-energy inputs (materials and services) by industry i in

[9]Equation 14 also includes a R&D tax credit variable at the country level as this is usually considered to be an important determinant of R&D investment decisions (Thomson 2013).

country c at time t. When a full set of Input-Output matrices is available, $III_{i,c,t}$ can be extracted from the import matrix and $NE_{i,c,t}$ from the use matrix. When I-O matrices are not available on an annual basis, $III_{i,c,t}$ is estimated under a "proportionality" hypothesis (assuming only one tradable good) as follows:

$$III_{i,c,t}=\tau_{i,c,t}III_{c,t}=\left(\frac{III_{i,c,t}}{III_{c,t}}\right)III_{c,t} \tag{8}$$

$III_{c,t}$ are total (economy-wide) imports of the tradable good, which are then multiplied by the share of industry's i to total (economy-wide) imports in a year t. Ratio $\tau_{i,c,t}$ is defined as the share of $III_{i,c,t}$ to $III_{c,t.}$ The value of τ is taken from the I-O matrix and it is initially available for benchmark years, 1995, 2000 and 2005. For post-1995 years τ is linearly interpolated while for pre-1995 years it is backwardly extrapolated applying the rate of change over the period 1995-2000. Non-energy expenses for intermediate inputs, $NE_{i,c,t}$ are taken from EUKLEMS database excluding fuels and mining products (Crinò, 2008).

Given that we distinguish between materials and services off-shoring (*MOS* and *SOS*, respectively), expression (7) is further disaggregated into:

$$MOS_{i,c,t}=\frac{\sum_{f=1}^{F} IMI_{i,c,t}^{f}}{NE_{i,c,t}} \tag{9}$$

$$SOS_{i,c,t}=\frac{\sum_{f=1}^{F} ISI_{i,c,t}^{f}}{NE_{i,c,t}} \tag{10}$$

The measures above are defined as *broad* indicators of off-shoring, as they include purchases of intermediate inputs (either material or services) from all foreign industries. A more narrowly defined indicator is obtained by considering only within-industry transactions (*narrow off-shoring)*. This measure captures the overseas transfer of parts of the production process which could have been performed in house.[10] The *narrow indicator* (*NOS*) is defined as follows:

$$NOS_{i,c,t}=\frac{III_{i,c,t}^{i'}}{NE_{i,c,t}} \text{ with } i'=i \tag{11}$$

where industry i' denotes the foreign partner of domestic industry i. Data on total imports distinguished by goods' type come from Bilateral Trade Database (various releases); for services trade we refer to OECD EBOPS database which,

[10]Examples of materials off-shoring include car manufacturing, when automobile parts are produced abroad while services off-shoring include software development or x-rays analysis; see, for a relevant discussion, Thurm (2004).

whenever necessary, has been integrated with UNCTAD series. All variables are expressed in current USD using OECD bilateral exchange rates.

The importance of using both broad and narrow measures of off-shoring is to investigate whether different types of international outsourcing have different effects on specialization. Figure 2 shows the main trends in the three off-shoring variables for each industry. It shows that movements in the three indicators are quite heterogeneous. Material off-shoring declined between 1990 and 2005 in most industries. Relatively high levels are still observed in the rubber and plastic industry and in the high-tech sectors (machinery, electrical equipment and transportation equipment). The latter sectors require highly skilled tasks (design/semiconductors) but also labor intensive activities (assembly) which can be easily transferred to low-wage countries (Jensen 2008). Service off-shoring has increased substantially in high-tech industries, while changes in the low-tech production have been more modest. The only exception is transport services, which experienced a strong reduction in service off-shoring, although this was over compensated by a large increase in narrow off-shoring, as shown in the last section of Figure 2. Narrow off-shoring increased in all high-tech industries as larger parts of their production moved abroad. The sector that more heavily relied on this practice is chemicals, which presented the highest level of narrow off-shoring over value added throughout the whole period, followed by electrical equipment and transport equipment. Low-tech industries were not immune to the use of narrow off-shoring, although a major increase can only be observed in transport services.

3.2. *Value Added, Technology and Factor Endowments*

The EUKLEMS data base is our main data source for value added at the industry level and for the construction of our technology measure. Following Caves *et al*. (1982) and Van Ark *et al*. (1993), technology is proxied by a Total Factor Productivity (TFP) index. TFP in each country is expressed relative to a hypothetical reference unit to keep consistency with our theoretical derivation in equation (1). The hypothetical unit is the geometric mean of TFP in the eight countries in each industry. Hence, RTFP (Relative Total Factor Productivity) is given by:

$$\begin{aligned} \ln RTFP_{i,c,t} &= \left(\log Y_{i,c,t} - \log \bar{Y}_{i,t}\right) \\ &- \tilde{a}_{i,c,t}\left(\log L_{i,c,t} - \log \bar{L}_{i,t}\right) - \left(1-\tilde{a}_{i,c,t}\right)\left(\log K_{i,c,t} - \log \bar{K}_{i,t}\right) \end{aligned} \tag{12}$$

In equation (12) Y is value added, L is labor and K is capital. A bar over a variable indicates the cross-country geometric mean. Labor share is measured as the ratio of labor compensation to value added and $\tilde{a}_{i,c,t} = \frac{a_{i,c,t} + \bar{a}_{i,t}}{2}$. Labor input in equation (12) accounts for heterogeneous labour by aggregating three types of workers identified according to their educational attainment (low, intermediate, and high skill),[11]

[11]The division of labor according to the level of educational attainment can cause some problems as the educational system has been subject to changes over time. The method used in EU-KLEMS ensures that this division is consistent over time for each country. See also O'Mahony and Timmer (2009).

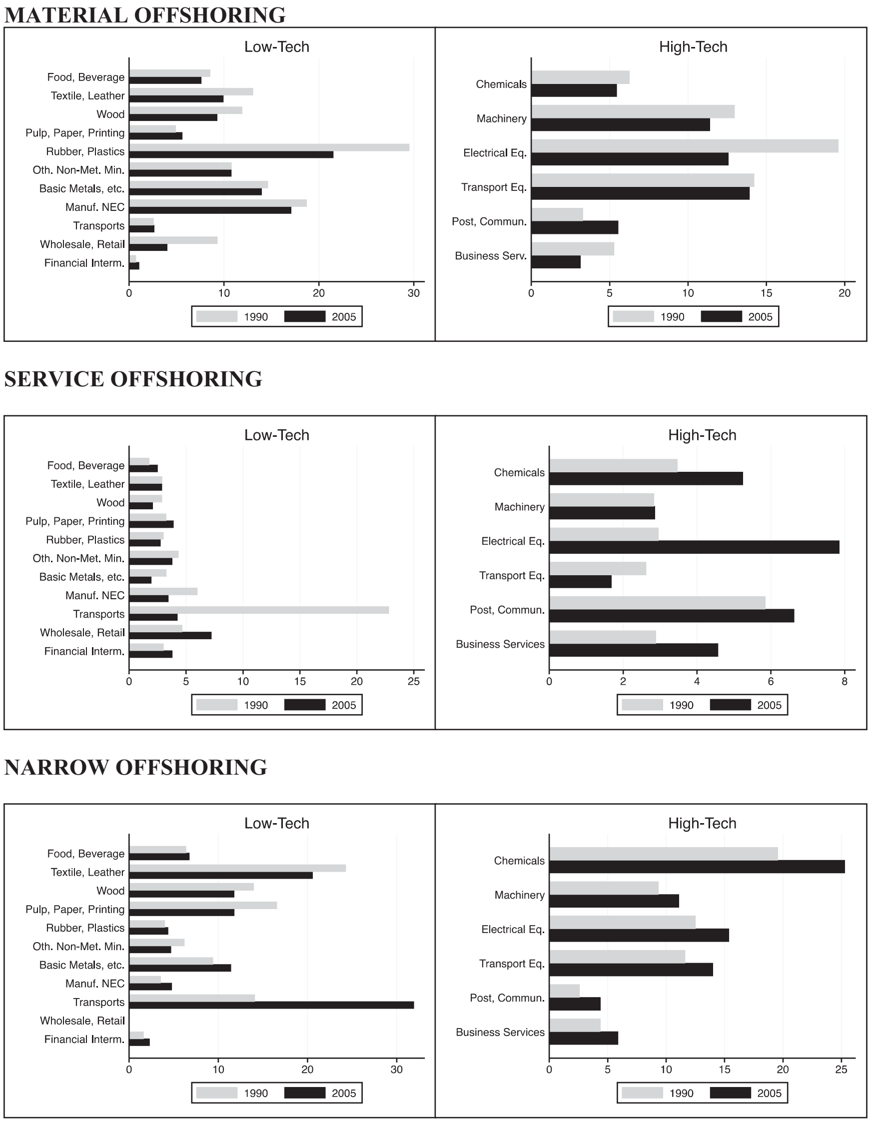

Figure 2. Off-shoring in High-Tech and Low-Tech Industries, 1990 and 2005 (cross-country averages)

Note: Figures represent average values for the eight countries included in our empirical analysis (Denmark, Finland, Germany, Italy, Japan, Netherlands, UK and USA). Off-shoring is expressed as a proportion of value added.

weighted by the share of each type in total labor compensation. Similarly, the construction of the capital stock is obtained by aggregating investment in ICT and non-ICT assets, weighted by the share of each asset in total capital compensation.

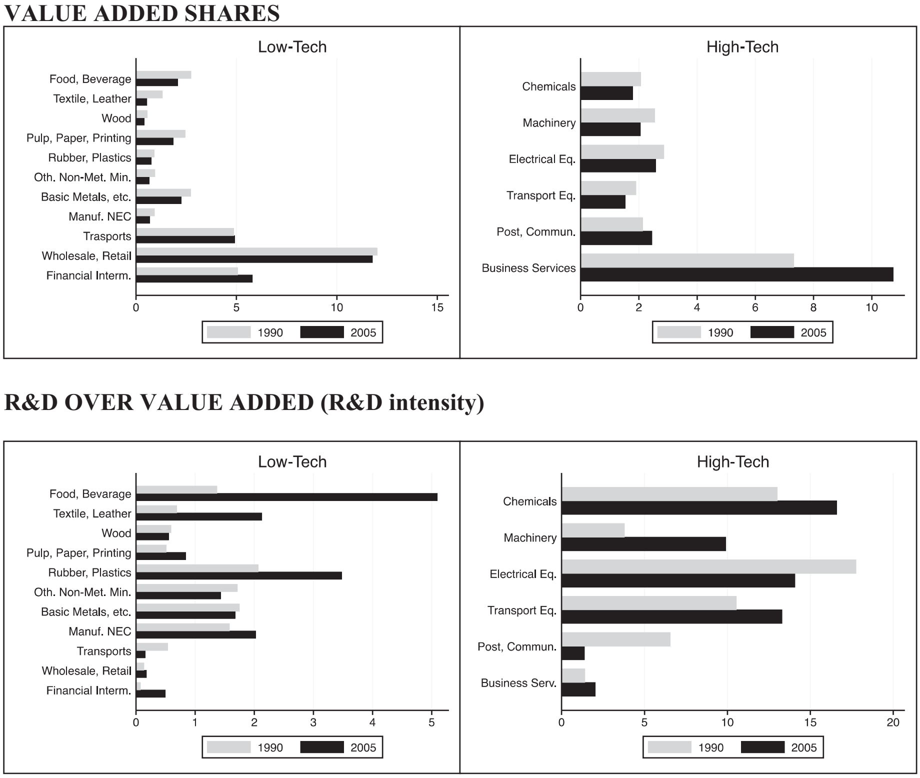

Figure 3. Industry Specialization and R&D investment, 1990–2005

Notes: Figures represent average values for the eight countries included in our empirical analysis (Denmark, Finland, Germany, Italy, Japan, Netherlands, UK and USA). Value added shares are computed as industry value added over GDP

We convert value added, labor, capital compensation and investment in capital assets in 1995 constant prices with industry price deflators (EU-KLEMS) and then into international US Dollars with GDP purchasing power parity (PPP) exchange rates (World Bank Development Indicators-International Comparison Program).

R&D expenditure data for the estimation of equation (6) are taken from various versions of the OECD ANBERD database. Finally, skilled labor endowments are classified according to educational level, SK for high skilled and *UNSK* for low and intermediate. Those data are taken from Barro and Lee (2001). Capital stocks at the country level are taken from the EUKLEMS data base.

Figure 3 presents value added shares (s) and R&D intensity (RDI) in 1990 and 2005, while summary statistics for the other variables are presented in appendix Table A.1 and A.2. Figure 3 shows that within manufacturing, electrical equipment is the most prominent sector in the early 1990s. All manufacturing sectors experienced a decline in their value added shares, particularly the low-tech manufacturing. Decreases in the high-tech manufacturing were generally quite modest. As a result of the deindustrialization process, the share of service sectors expanded rapidly in the OECD area, particularly in business services and in financial intermediation. In fact, business services, together with wholesale and retail trade, had the highest share of value added to GDP in 1990 and remain the largest sectors at the end of the period, with business services experiencing an increase of over 3 percentage points.

Changes in R&D intensity over time clearly show that the vast majority of manufacturing industries have increased investment in R&D. The only noticeable exception is the electrical equipment industry which, *on average*, experienced a decrease in R&D intensity between 1990 and 2005. Despite this decrease, it is still among the sectors with the highest R&D intensity, second only to the chemical industry. A particularly interesting trend is the increase of R&D intensity in several traditional industries such as food and beverages, textile and rubber and plastics. A possible explanation for this trend is that these industries had to adopt innovative technologies that significantly improved their product quality, in an attempt to move towards higher segments of the market and thus avoid the low cost competition from developing countries (Martin and Mejean 2014; Bloom *et al*. 2016).

4. Econometric Strategy

The estimation of the endowment (eq. 3) and productivity channels (eqs. 5 and 5.2) requires addressing the issues of heterogeneity and endogeneity. Since we are interested in how country specialization changes in response to offshoring, our estimation is carried out industry by industry for each specification and hence sectoral heterogeneity is fully accounted for. However, neglecting country effects could lead to biased coefficient estimates. We therefore include country fixed effects in all specifications to control for unobserved, time invariant heterogeneity across nations. In addition, we also include time dummies to account for exogenous time varying unobservable effects on specialization that are common across countries.

In Harrigan's (1997) seminal paper the issue of endogeneity was not specifically addressed as factor endowments are regarded as exogenous with respect to variations in industry specialization. However, the relative productivity term is likely to pose more serious endogeneity concerns. In fact, it is possible that changes in value added shares determine variation in relative TFP (Frantzen 2008), as firms may specialize in certain productions anticipating significant increases in technology (and productivity) levels. To address this endogeneity issue we use a set of variables (instruments) that satisfy the two conditions for instrument validity: they have to be related to the endogenous variable (RTFP) while, at the same time, being orthogonal to the error term (and hence to value added shares). Possible candidates are the lagged values of relative TFP, under the assumption that these are uncorrelated with the errors at time t. However, relative TFP is highly persistent in the majority of industries, which invalidates its use as an instrument.[12]

Finding *good* external instruments is a particularly challenging exercise, as (exogenous) factors driving TFP are likely to be industry specific. The advantage of our regression framework is that it exploits cross-country variation in the data to explain changes in industry share of GDP. This allows us to construct a large set of instruments, reflecting several country-specific characteristics (institutional setting, regulation policies, geographical characteristics, etc.) that have been found to be related to TFP in the earlier literature. We then select, for each industry, a subset of instrumental variables that satisfy the relevance and orthogonality conditions, as detailed by the outcome of the two main tests for instrument validity routinely produced by econometric software, i.e. the Kleinbergen-Paap LM test of under-identification and the Hansen J test of over-identification.

An important source of our instrument set is the CANA (cross-country analyses of national systems) data base (Castellacci and Natera 2011). This dataset is a collection of cross-country data from different sources, adjusted to eliminate missing observations, using multiple imputations. From this data set we select variables belonging to three dimensions: innovation and technological capabilities, economic competitiveness, and infrastructure. From the first dimension we use the number of scientific and engineering articles published in scientific fields per thousands of people. This variable is likely to be correlated to TFP while correlation with the error term is less obvious. To capture the relationship between TFP and competitiveness we use indicators such as enforcing contract time, finance freedom, trade freedom[13]. The infrastructure field provides information on the diffusion of PCs, the Internet, mobile phones, electric power consumption and road conditions. These infrastructure variables are strongly related to TFP, as documented in Yeaple and Golub (2007) but less correlated to industries' value added shares and are therefore good candidates for our instrumentation strategy.

This set of indicators is complemented with information on military expenditure and the price of oil (Source: OECD and EU KLEMS), the OECD index of upstream product market regulation (Conway *et al*. 2006) and intellectual property rights (IPR) protection (Ginarte and Park 1997). It is well established that military expenditure and oil price explain a large variation in TFP changes in industrialized countries, as discussed in Hall (1989) and Vecchi (2000). Similarly, restrictive regulation in the use of service intermediates reduces the potential for TFP growth, as shown by Bourlès *et al* (2013). Moreover, productivity improvements can be achieved in the presence of well-defined rules on IPRs as these promote innovations (Aghion *et al*. 2015).

[12]We carried out the estimation using lagged levels of relative TFP as an instrument and results were very similar to those generated using OLS. This suggests that this instrumentation strategy does not fully address the endogeneity problem. Results are available on request.

[13]Enforcing contract time refers to the number of days needed to enforce a contract. Days are counted from the moment the plaintiff files the lawsuit in court until payment. Low (high) values of the variable indicate high competitiveness. Finance freedom is a subjective assessment of Heritage staff, comparable over time. Trade freedom is a composite measure of the absence of tariff and non-tariff barriers that affect imports and exports of goods and services (O'Grady *et al*. 2006).

The estimation of the R&D intensity equation (Equation 6) may also be affected by reverse causality. In fact it is likely that the increase in off-shoring has been the result of innovation, particularly for service off-shoring, and therefore we cannot rule out the possible impact of R&D on off-shoring (Bartel *et al.* 2005, Görg and Hanley 2011). We therefore instrument off-shoring using infrastructure variables, a corruption perception index and an indicator of the freedom to trade internationally. The infrastructure variables are related to off-shoring to the extent that they raise firms' connectivity and hence their ability to access both domestic and foreign input markets. Levels of corruption have traditionally been related to FDI in several countries as they reduce international investments flows (Wei 2000). The indicators of freedom to trade internationally, extracted from the Economic Freedom of the World Data (Gwartney and Lauwson 2014) summarize a variety of constraints on international trade, such as tariffs, quotas and control on exchange rates. It is reasonable to assume that these indicators, while closely related to off-shoring, are exogenous to industries' decision to invest in R&D as these are mainly driven by technological factors rather than corruption levels and tariffs.

5. Econometric Results

5.1. *The Endowment Channel*

We begin our analysis with the estimation of Equation (3) where sectoral output shares to GDP are determined by relative TFP (RTFP), average cross industry productivity $\left(\frac{1}{n-2}\sum_{m\neq i}^{n-1}\ln RTFP_{m,c,t}\right)$ and national factor endowments. The latter include material and service off-shoring at the national level (MOS and SOS), along with the traditional endowments of physical capital (K), skilled (SK) and unskilled (UNSK) labor. We estimate equation (3) using an instrumental variable estimator with covariance matrix robust to heteroscedasticity and serial correlation, following the instrumentation strategy documented in the previous section.

Table 1 presents our results. Starting with the coefficient of own industry RTFP, our analysis shows that the effect is predominantly positive, particularly among high-tech industries, consistent with the theory and previous evidence (Harrigan 1997). This impact is particularly high in electrical equipment, machinery NEC, and transport equipment where a 10 percent increase in relative TFP generates an increase in VA shares of 0.34, 0.27 and 0.2 percentage points respectively.[14] The coefficient on the average cross-industry productivity term is also positive in several industries, which indicates the existence of positive cross-industries technological spillovers. Thus, our findings suggest that some industries, such as post and telecom, food, transport services and financial intermediation, benefit from increasing productivity performance in other sectors.

Results for the off-shoring indicators show that material off-shoring (MOS) has a positive and statistical coefficient in three out of six high-tech industries, (transport equipment and post and telecom). The largest effect is found in

[14]Note that all coefficient estimates are semi-elasticities except for material and service off-shoring.

TABLE 1
Off-shoring and Specialization: Endowment Channel (Instrumental Variable Estimates)

	RTFP	AVG RTFP	MOS	SOS	K	SK	UNSK	KP	HJ
High-Tech									
Chemicals	−0.602*	0.459	−0.005	0.028**	−3.093***	−3.529***	0.809***	14.8	0.28
	(0.352)	(0.346)	(0.018)	(0.013)	(0.393)	(1.024)	(0.115)	[0.00]	[0.60]
Machinery, NEC	2.666**	−2.399*	0.084***	−0.001	−5.289***	4.736***	1.076***	9.5	0.05
	(1.082)	(1.297)	(0.026)	(0.013)	(0.781)	(1.371)	(0.276)	[0.01]	[0.82]
Electrical equipment	3.438***	−2.269**	−0.021	0.047	−19.22***	9.036***	−1.852**	28.0	2.84
	(0.543)	(1.120)	(0.054)	(0.033)	(2.281)	(2.997)	(0.786)	[0.00]	[0.24]
Transport equipment	2.037***	−3.966***	0.096***	0.065	0.261	−3.234	−0.164	11.5	0.63
	(0.533)	(1.245)	(0.036)	(0.041)	(0.983)	(2.318)	(0.283)	[0.00]	[0.43]
Post & telecoms	1.098***	0.810***	0.057***	−0.020	−1.668***	5.378***	0.539*	31.8	2.95
	(0.304)	(0.291)	(0.015)	(0.014)	(0.522)	(0.954)	(0.288)	[0.00]	[0.23]
Business services	0.791	−1.644***	−0.116***	0.041	2.477**	14.635***	0.701	12.5	0.63
	(0.655)	(0.609)	(0.033)	(0.032)	(1.042)	(1.753)	(0.650)	[0.00]	[0.43]
Low-Tech									
Food, beverages	−2.801***	3.601***	0.061***	0.011	−0.900	2.807	0.345	15.9	2.85
	(0.672)	(1.107)	(0.020)	(0.026)	(1.142)	(1.976)	(0.290)	[0.00]	[0.24]
Textile, leather	0.474*	0.509	−0.020**	0.030***	−1.160***	−0.742	0.299***	21.9	0.87
	(0.245)	(0.448)	(0.008)	(0.008)	(0.258)	(0.491)	(0.103)	[0.00]	[0.35]
Wood & cork	−0.112	0.327**	−0.015***	−0.000	−0.517	−0.286	0.022	12.4	0.12
	(0.107)	(0.161)	(0.005)	(0.006)	(0.324)	(0.449)	(0.040)	[0.00]	[0.72]
Pulp, paper	1.558*	−0.131	0.054**	−0.034	−1.655**	1.234	−0.344	21.9	0.67
	(0.899)	(0.845)	(0.021)	(0.024)	(0.757)	(1.384)	(0.334)	[0.00]	[0.71]
Rubber & plastic	0.268**	−0.093	0.024***	0.005*	−1.401***	0.776**	0.110**	26.6	1.12
	(0.104)	(0.104)	(0.003)	(0.003)	(0.260)	(0.315)	(0.050)	[0.00]	[0.29]
Non-metallic minerals	−0.506**	0.100	0.014**	−0.001	−0.015	0.315	0.616***	26.1	0.19
	(0.247)	(0.139)	(0.006)	(0.005)	(0.212)	(0.378)	(0.083)	[0.00]	[0.66]
Basic metals	1.914	−1.186	0.073***	0.019	−6.136***	1.555	0.733**	6.6	0.02
	(1.219)	(0.860)	(0.010)	(0.018)	(1.199)	(0.947)	(0.322)	[0.04]	[0.88]
Manufacturing NEC	−0.263*	0.276**	−0.003	0.002	−0.234	1.535***	0.481***	20.7	0.11
	(0.153)	(0.135)	(0.005)	(0.005)	(0.193)	(0.353)	(0.080)	[0.00]	[0.74]
Transport & storage	0.833***	−2.060***	0.042***	0.072***	−2.914***	−0.937	0.459***	33.6	0.21

Table 1 *Continued*

	RTFP	AVG RTFP	MOS	SOS	K	SK	UNSK	KP	HJ
	(0.290)	(0.245)	(0.011)	(0.019)	(0.426)	(0.790)	(0.130)	[0.00]	[0.65]
Wholesale & retail	−3.171	5.364***	−0.067*	0.052*	7.930***	−7.205	−0.869	11.5	0.02
	(2.332)	(1.899)	(0.036)	(0.029)	(2.484)	(5.964)	(0.547)	[0.00]	[0.88]
Financial intermediation	−1.628	2.680***	−0.207***	−0.122*	1.381	−4.586*	−0.095	13.6	1.79
	(1.154)	(0.689)	(0.036)	(0.072)	(1.510)	(2.693)	(0.555)	[0.00]	[0.18]

Notes: GMM estimates with HAC standard errors in parentheses. Standard errors in parentheses. Country fixed effects and common time dummies are included in all equations. For each industry we have 128 observations. The R^2 ranges between 0.78 in Financial Intermediation, and 0.99 in Wholsesale and retail. The KP is the Kleibergen-Paap underidentification test of the null hypothesis that the excluded instruments are irrelevant. HJ is the Hansen J overidentification test of the null hypothesis that the instruments are uncorrelated with the error term. P values for these tests are reported in brackets.

*Significant at 10%; **significant at 5%; ***significant at 1%.

transport equipment as a 1 percentage point increase in material off-shoring increases the GDP share of this industry by 0.10 percentage points. Six low-tech industries are also positively affected by material off-shoring (food and beverages, pulp and paper, rubber and plastic, non-metallic minerals, basic metals and wholesale and retails). A negative and significant effect of material off-shoring is considerably less common (4 out 17 industries).

The effect of service off-shoring is weaker compared to material off-shoring, as it plays a significant role only in a handful of industries. This is *per se* an interesting outcome as it indicates that material and service off-shoring do not have a homogeneous effect on specialization. This outcome is consistent with Crinò (2012), where service and material off-shoring have a different impact on the demand for skilled and unskilled workers.

Turning to the traditional factor endowments, total accumulation of physical capital tends to be a negative factor in most industries, particularly within the manufacturing sector.[15] Our results also show that larger stocks of skilled labor increase valued added shares in several industries, particularly among the high-tech sectors (machinery, electrical equipment, post and telecommunications and business services). The strongest effect is in business services where a 1 percent increase in the endowment of workers with a university degree (and above) increases valued added shares by approximately 0.15 percentage points.

Overall these results provide some support to our first hypothesis, i.e. off-shoring is reallocating resources towards high-tech industries, although with two caveats. First, one of the largest high-tech industries, business services, is negatively affected by material off-shoring; second, several low-tech industries also benefit from increasing off-shoring of intermediate materials.

Given that our variables are expressed in different units of measurement, to get a better idea of the size of the effect, we derive standardized coefficients, reported in Appendix Table A.3. These shows that, where positive, one standard deviation increase in material off-shoring leads to between 0.15 and 0.60 standard deviation increase in the value added shares, and this effect is in several cases larger than the impact of relative productivity. Although traditional factors such as capital and labor are still the main drivers of specialization, off-shoring is also responsible for important changes in the industrial structure of OECD countries.

5.2. *The Productivity Channel*

This part of the analysis refers to the productivity channel where RTFP is expressed as a function of industry-level off-shoring, equations (5.1) and (5.2). In this section we also refine the treatment of off-shoring, differentiating between broad measurements of off-shoring such as material and services (MOS^{ind} and SOS^{ind}) and intra-industry (narrow) off-shoring, (NOS^{ind}). Broad and narrow off-shoring measures are entered separately in equation (5.2) to avoid possible collinearity issues.

[15]This result contradicts Leamer (1984) and Harrigan's (1995) finding on the positive role of capital accumulation on manufacturing output for earlier periods. However, in these studies comparative advantage was only driven by factor accumulation without accounting for productivity and off-shoring effects.

TABLE 2

Productivity Channel with Narrow Off-shoring (Instrumental Variable Estimates)

	First stage Narrow Off-shoring (Equations (5.1))	Second stage RTFP (Equation (5.1))	R^2	KP	HJ
High-Tech industries					
Chemicals	−0.006***	0.265	0.93	22.6	0.00
	(0.002)	(0.216)		[0.00]	[1.00]
Machinery	0.019***	1.902***	0.96	18.0	1.34
	(0.005)	(0.519)		[0.00]	[0.51]
Electrical equipment	−0.025***	6.906***	0.51	6.64	0.48
	(0.009)	(1.481)		[0.04]	[0.49]
Transport equipment	0.023**	0.710**	0.98	9.30	0.41
	(0.008)	(0.243)		[0.00]	[0.52]
Post & telecoms	0.012	1.292***	0.78	26.5	2.92
	(0.008)	(0.411)		[0.01]	[0.23]
Business services	0.006	−0.788	0.98	15.9	0.84
	(0.008)	(−0.945)		[0.00]	[0.66]
Low-tech industries					
Food & beverages	0.023***	0.098	0.93	11.3	0.03
	(0.008)	(0.600)		[0.00]	[0.87]
Textile & leather	0.005***	−1.062***	0.98	14.0	3.58
	(0.001)	(0.332)		[0.02]	[0.17]
Wood & cork	0.000	−0.168	0.96	17.1	7.87
	(0.005)	(0.153)		[0.01]	[0.05]
Pulp & paper	0.002	0.690	0.96	12.6	2.63
	(0.002)	(1.232)		[0.00]	[0.10]
Rubber & plastic	−0.003	−0.129	0.92	30.6	11.1
	(0.006)	(0.133)		[0.00]	[0.01]
Non-metallic minerals	0.010	−0.924*	0.89	11.9	3.54
	(0.006)	(0.478)		[0.01]	[0.12]
Basic metals	−0.005	1.714	0.96	7.99	2.44
	(0.006)	(1.378)		[0.02]	[0.13]
Manufacturing .NEC	−0.015	−1.704***	0.95	15.5	5.72
	(0.015)	(0.208)		[0.03]	[0.12]
Transports	0.004***	1.219*	0.99	21.0	0.49
	(0.001)	(0.685)		[0.00]	[0.49]
Financial intermediation	0.020***	2.620***	0.83	13.8271	0.00
	(0.250)	(0.673)		[0.00]	[0.99]

Notes: GMM estimates with HAC standard errors in parentheses. Country fixed effects and time dummies are included in all equations. The first step also includes a subset of external instruments. The full list of instruments is presented in appendix table A.1. KP is the Kleibergen-Paap underidentification test of the null hypothesis that the excluded instruments are irrelevant. HJ is the Hansen J overidentification test of the null hypothesis that the instruments are uncorrelated with the error term. P values for these tests are reported in brackets.

*Significant at 10%; **significant at 5%; ***significant at 1%.

As in the previous section we implement an instrumental variable estimator. In the first stage RTFP is regressed on the set of instruments described in Section 4, next to our off-shoring measures at time (t-1).[16] In the second stage, value added shares are regressed on the predicted RTFP values and economy wide factor endowments. The main results relative to the off-shoring coefficient in the first step, and to RTFP in the second step are presented in Table 2 (for narrow off-shoring) and Table 3 (for material and service off-shoring), together with a set of

[16]We include the predetermined values instead of the contemporaneous ones to control for the possible endogeneity of off-shoring in the first stage regression.

TABLE 3
Productivity Channel – Material and Services Off-shoring. (Instrumental Variable Estimates)

	First stage (Equation 5.2) Dep.: RTFP		Second stage (Equation 5.1) Dep: VA shares			
	Material Off-shoring	Servive Off-shoring	RTFP	R^2	KP	HJ
High-Tech industries						
Chemicals	−0.050***	0.017**	−0.021	0.93	32.53	5.93
	(0.010)	(0.010)	(0.210)		[0.00]	[0.21]
Machinery	−0.006	0.021***	−2.014***	0.95	14.36	1.91
	(0.004)	(0.008)	(0.924)		[0.01]	[0.59]
Electrical equipment	−0.029***	−0.002	4.277***	0.84	23.2	0.23
	(0.003)	(0.010)	(0.409)		[0.00]	[0.89]
Transport equipment	−0.011	0.033*	1.113***	0.97	12.1	0.31
	(0.013)	(0.018)	(0.376)		[0.01]	[0.86]
Post & telecoms	0.026***	−0.007	−1.339	0.68	11.4	6.66
	(0.009)	(0.005)	(0.675)		[0.02]	[0.08]
Business services	−0.008	−0.101***	2.930***	0.97	38.5	4.20
	(0.008)	(0.023)	(0.739)		[0.00]	[0.24]
Low-tech industries						
Food & beverages	−0.015**	−0.031*	−1.313***	0.92	22.6	7.65
	(0.006)	(0.019)	(0.253)		[0.00]	[0.11]
Textile & leather	0.007*	0.033***	−0.741***	0.98	22.6	5.67
	(0.003)	(0.011)	(0.240)		[0.00]	[0.13]
Wood & cork	0.023**	−0.037**	−0.701**	0.95	13.3	1.88
	(0.010)	(0.015)	(0.294)		[0.01]	[0.60]
Pulp & paper	−0.004	−0.033***	−3.198***	0.97	35.0	6.71
	(0.006)	(0.008)	(0.618)		[0.00]	[0.15]
Rubber & plastic	0.004***	0.027**	0.001	0.93	28.90	18.6
	(0.002)	(0.010)	(0.121)		[0.00]	[0.00]
Non-metallic minerals	0.004	−0.013***	1.121***	0.91	16.65	6.52
	(0.004)	(0.004)	(0.386)		[0.01]	[0.16]
Basic metals	−0.006***	0.012**	−2.993***	0.90	12.7	1.69
	(0.002)	(0.006)	(1.248))		[0.01]	[0.43]
Manufacturing NEC	0.016***	−0.001	−0.355***	0.96	20.7	4.53
	(0.003)	(0.004)	(0.136)		[0.00]	[0.12]
Transport & storage	−0.049***	0.002**	1.139**	0.99	24.9	3.28
	(0.010)	(0.00101)	(0.455)		[0.00]	[0.35]
Wholesale & retail	0.003	−0.001	2.833*	0.95	28.66	19.41
	(0.002)	(0.003)	(1.702)		[0.01]	[0.01]
Financial intermediation	−0.194***	0.075***	0.538	0.81	22.94	16.78
	(0.053)	(0.013)	(0.773)		[0.00]	[0.00]

Notes: GMM estimates with HAC standard errors in parentheses. Country fixed effects and common time dummies are included in all equations. See Table A.5 in the Appendix for the full set of estimates. KP is the Kleibergen-Paap underidentification test of the null hypothesis that the excluded instruments are irrelevant. HJ is the Hansen J overidentification test of the null hypothesis that the instruments are uncorrelated with the error term. P values for these tests are reported in brackets. P-values of Hansen test are reported in square brackets. Country fixed effects and common time dummies are included in all equations.

*Significant at 10%; **significant at 5%; ***significant at 1%.

identification tests. The full set of coefficient estimates is presented in Appendix Tables A.4 and A.5.

Our findings show that narrow off-shoring has a positive and significant effect on RTFP in two high-tech industries (machinery and transport equipment). In the low-tech sectors, the effect is positive in the majority of industries although coefficients are statistically significant only in four of them (food, textile, wholesale and retail and financial intermediation). Table 3 shows that materials and service off-shoring are often characterized by opposing signs across industries indicating that potential productivity gains depend on the type of off-shoring activity undertaken. Our results are consistent with recent evidence from Michel and Rycx (2014) for a sample of Belgium industries during a very similar time span. Only two industries significantly benefit from both types of off-shoring (textile and leather; rubber and plastic). Service off-shoring has more widespread positive impact on productivity, particularly in the low-tech industries where the coefficient is positive and significant in five sectors.

Looking at the second stage results, i.e. the impact of relative TFP in the valued added share equation, Tables 2 and 3 show that productivity improvements are driving specialisation mainly among high-tech sectors, while the effect is negative or insignificant in low-tech ones, with only a couple of exceptions. This implies that countries are experiencing a technological specialization, driven by productivity improvements in high-tech industries. However, these improvements are only marginally related to off-shoring.

Overall, results from the estimation of the productivity channel provide weak support to hypothesis 2, i.e. off-shoring drives specialisation by improving within industry productivity. A possible explanation for these findings is that off-shoring is likely to require organizational and restructuring costs at the firm level hence potential gains from these inter-industry (input-output) transactions take relatively longer to be capitalized. Another possibility is that off-shoring practices have an indirect impact on productivity via their effect on those activities that ultimately drive TFP dynamics. For this reason, in the next section we investigate the nature of the association between off-shoring and R&D, a widely acknowledged determinant of productivity performance. If the channel of transmission of the productivity effects of off-shoring is through R&D, results in Table 2 and 3 would not exclude a negative association between R&D intensity and off-shoring, in contrast to the prediction of hypothesis 3.

5.3 *Off-shoring and Industries' Investments in R&D*

The estimation of the productivity channel reveals that the impact of industry off-shoring is taking place mainly within rather than across industries; here we explore this industry effect further by testing hypothesis 3, off-shoring promotes investment in R&D, via the estimation of equation (6). Most empirical evidence so far suggests the presence of a positive effect of off-shoring on R&D and innovation. Görg and Hanley (2011) find that off-shoring positively affects R&D expenditure over sales in Irish companies. Dachs *et al*. (2015) use a more comprehensive definition of innovation distinguishing between R&D personnel, introduction of new products and advanced process technologies. Using firm level data for seven EU countries, they show that the positive impact of off-shoring affects all innovation types.

TABLE 4
R&D Equation: Results for Narrow, Material and Service Off-Shoring (Instrumental Variable Estimates)

	NOS industry	MOS industry	SOS industry
High-Tech industries			
Chemicals	−0.547***	−1.577	−0.560
	(0.104)	(1.101)	(0.866)
Machinery, NEC	−0.708	−0.252*	−0.094
	(0.520)	(0.139)	(0.201)
Electrical equipment	−2.091***	0.864***	3.297***
	(0.391)	(0.331)	(0.976)
Transport equipment	−1.204***	−0.123	0.369
	(0.308)	(0.328)	(0.617)
Post & telecoms	−0.931	−8.051***	1.216**
	(1.008)	(1.995)	(0.534)
Business services	0.303	−0.305**	0.981***
	(0.303)	(0.139)	(0.309)
Low-tech industries			
Food, beverages	−1.010*	1.197	−1.538
	(0.587)	(0.860)	(1.424)
Textile, leather	−0.064**	0.163	0.351*
	(0.032)	(0.108)	(0.198)
Wood & cork	0.009	−0.031	−0.182
	(0.062)	(0.058)	(0.118)
Pulp & paper	−0.052**	0.066	−0.100
	(0.024)	(0.058)	(0.067)
Rubber & plastic	−0.740***	−0.113***	−0.607***
	(0.159)	(0.038)	(0.208)
Non-metallic minerals	−0.176*	−0.236*	−0.108
	(0.093)	(0.132)	(0.099)
Basic metals	−0.180*	−0.004	−0.288***
	(0.099)	(0.042)	(0.074)
Manufacturing NEC	−0.470*	−0.020	0.520**
	(0.269)	(0.091)	(0.220)
Transports	0.017	−0.450***	0.003
	(0.011)	(0.138)	(0.008)
Financial Intermediation	0.133***	2.183**	0.118
	(0.039)	(1.001)	(0.127)

Notes: GMM estimates with HAC standard errors in parentheses. We exclude Wholesale and Retail sector as they do not report any narrow off-shoring variables. Country fixed effects and common time dummies are included in all equations.
*Significant at 10%; **significant at 5%; ***significant at 1%.

Equation (6) is estimated separately for the narrow and broad off-shoring indicators.[17] To simplify the discussion of our results, Table 4 shows the estimated coefficients for all off-shoring measures. The full set of results is in Appendix Tables A.6 and A.7. Results in Table 4 reveal that there is considerable heterogeneity in the way off-shoring affects industries' decision to invest in R&D. Narrow and material off-shoring have a predominantly negative effect, hence rejecting our third hypothesis. Service off-shoring, on the other hand, plays a positive role in increasing R&D intensity in three high-tech industries (electrical equipment, post and telecommunications and business services) and two low-tech sectors (wood and manufacturing, NEC). Hence only for this

[17]We also estimated a specification including the three off-shoring variables and the results were consistent with the ones presented in Table 4. We prefer to treat narrow and broad off-shoring measures separately for consistency with the estimation of the specialization equation.

handful of industries our evidence is in line with existing empirical studies. These results are consistent with those in the productivity channel, where we found that only service off-shoring has a positive impact on RTFP. Results in Table 4 are robust to different specifications of the R&D equation and to the choice of different instrumental variables.[18]

This predominantly negative association suggests that R&D and off-shoring act as substitute rather than complementary factors. A similar result is found in Karpaty and Tingvall (2015), who argue that off-shoring is mainly pursued for cost minimization purposes. Another explanation for the negative impact of off-shoring on R&D is that the increasing international fragmentation of production reduces plant-level economies of scale (Barba Navaretti and Falzoni 2004) and/or minimizes feedback of technical information from foreign plants to domestic research labs (Naghavi and Ottaviano 2009).

6. Conclusions

This paper provides an analysis of the impact of off-shoring on specialization and R&D intensity and investigates whether off-shoring is fostering specialization towards more technologically advanced production patterns. We first construct two testable regression frameworks, which identify the impact of off-shoring via an endowment and a productivity channel. As a corollary of these two frameworks we also test a third hypothesis which postulates a positive relationship between off-shoring and R&D. Looking at the endowment channel, we find that material off-shoring has a positive impact on the output share of the majority of high-tech industries, a result that supports our main hypothesis. However, several low-tech industries also benefit from material off-shoring.

Estimation of the productivity channel provides weak evidence of a positive impact of off-shoring on productivity. The final part of our analysis suggests that this loss of productivity may be caused by a negative impact of off-shoring on industries' R&D intensity. Only service off-shoring increases R&D intensity in some sectors and, as a result, we have to reject at least partially our third hypothesis. Industry heterogeneity and different effects across the off-shoring measures prevent us from drawing stronger conclusions. This is not totally unexpected as related evidence on off-shoring in particular, and trade openness in general, has generated various contradictory conclusions in the recent literature.[19] It is also possible that the level of aggregation of our data might be the cause of this negative result as the existing empirical evidence of a positive relation between off-shoring and R&D is based on firm level data.

Our results indicate that the weak effect of off-shoring on R&D stems from firms' myopic behavior, which focuses more on short-term cost gains rather than on restructuring and diverting resources towards more innovative activities. This motive explains why firms revised their practices of internationalisation of

[18]We also estimated Eq. 6 using OLS introducing offshoring at time (t-1) to control for endogeneity, as well as with an IV regression using lagged levels of off-shoring as instruments. Results are consistent to those presented in Table 4.

[19]See, for example, the literature on the declining trends in labor shares where there is an open debate on the relative importance of trade openness (Gushina 2006, Elsby *et al*. 2013) versus technology (Hutchinson and Persyn 2012).

production as a consequence of the financial crisis, re-shoring parts of the tasks previously located abroad.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Table A1: Industry level variables: average values
Table A2: Country level variables: average values
Table A3: Off-shoring and Specialization: Endowment Channel (Standardized Coefficients)
Table A4: Off-shoring and Specialization: Productivity channel Narrow Off-shoring (2nd stage estimates)
Table A5: Off-shoring and Specialization: Productivity channel Broad Off-shoring (2nd stage estimates)
Table A6: R&D intensity equation with narrow off-shoring (Instrumental variable estimates)
Table A7: R&D intensity equation with material and service Off-shoring (Instrumental variable estimates)